Enabling Materials for Indirect Fire Weapon Systems

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Enabling Materials for Indirect Fire Weapon Systems

- horizontal technology
- historical usage
- broad application
- cost-effective….especially considering life cycle
- enablers for lethality, survivability, logistics transformation
- technology toolkit for all weapons designers

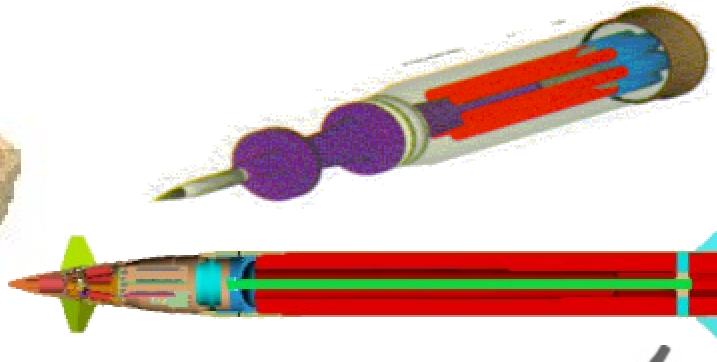
Composite Materials

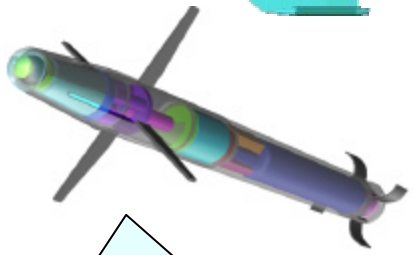
The FCS+ Field of Play

Integral Armor

Lightweight Armaments

Advanced Munitions





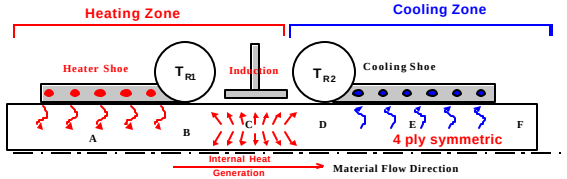
- Composite Over-wrapped Cannon
- Ceramic-Lined Barrels
- Lightweight MRAAS Components
- Composite Over-wrap Mortar Tubes

- Multifunctional Lightweight Vehicular Armor
- Nanomaterial-based Transparent Armor
- Shock Mitigation in Composite Armor Structure
- Graded Structures/Controlled Interphases
- Transient Progressive Failure Mechanics
- Low-cost Processing/Repair
- Embedded Sensors/Integrated Signature

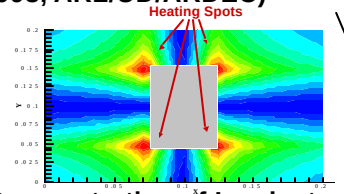
- Kinetic Energy Projectile Sabots
- Smart Piezoelectric Control Surfaces
- Ejectable Composite Cases
- Composites for Insensitive Munitions
- MMC Shells

Materials Technology Success Story

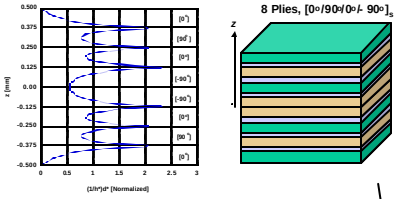
Electromagnetic Processing of Composites



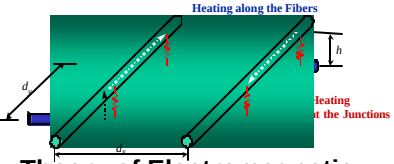
Laminator Concept Validation in Lab (1998, ARL/UD/ARDEC)



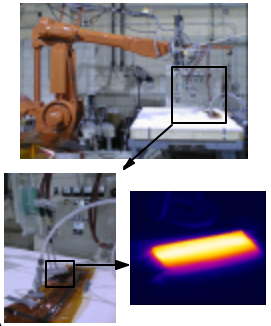
Demonstration of Laminate Heating (1996, ARL/UD)



Theory of Heating in Composites (1991, ARL/UD)



Theory of Electromagnetic Heating in Fibrous Systems (1989, ARL/UD)



Prototype Machine Validated (1999, ARL/UD/ATK/ARDEC)

Processed Laminates (2000, ARL/UD/ATK)

EM Lamination Factory Operational (2000, ATK)

M829E3 Projectile Sabots Fired (2001, ATK/ARDEC/PM TMAS)

1. Basic principles observed and reported.
2. Technology concept and/or application formulated.
3. Analytical and experimental critical function/proof of concept.
4. Component/breadboard validation in laboratory environment.
5. Component/breadboard validation in relevant environment.
6. Subsystem prototype demo in relevant environment.
7. System prototype demo in an operational environment.
8. Actual system “flight qualified”
9. Actual system “flight proven”

Lightweight Mortars

Objective:

Decrease the weight of 81mm and 120mm Mortar Systems.

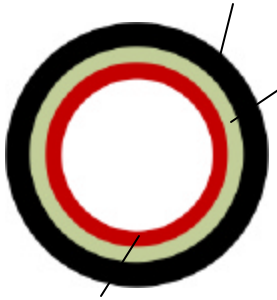
Technical Barriers:

- **Limitations of ltwt materials' thermal capacity**
  - **Loss of yield strength at elevated temp.**
  - **Degradation of composite matrix**
- **High firing rate requirements**
  - **81-mm: 30 rpm for 2 min; 15 rpm sustained**
  - **120-mm: 16 rpm for 1 min; 4 rpm sustained**
  - **Finite # of rounds in firing scenario make lightweight systems more viable**

Design Approaches:

Polymer-Matrix Composites

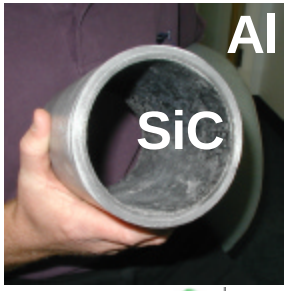
High temperature composites (IM7/RP46 polyimide)



LOCKHEED MARTIN

Metal-Ceramic-Metal Composites

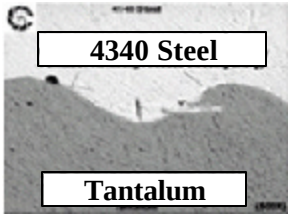
- **Integrated MMC/CMC barrel wall**
- **Fully dense CMC liner**
- **Fully dense AMC jacket**

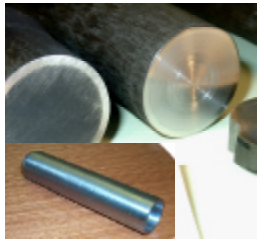


tsi

Ceracom

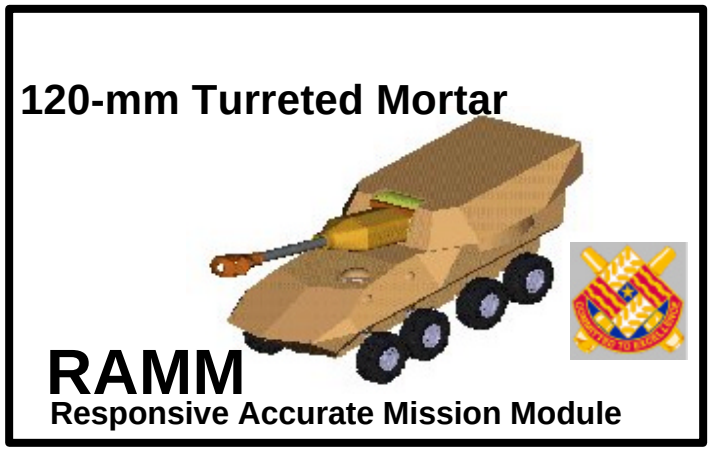
Refractory Metal Cladding





TPL, INC.

Applications:



Artillery Gun Tubes

Objective:

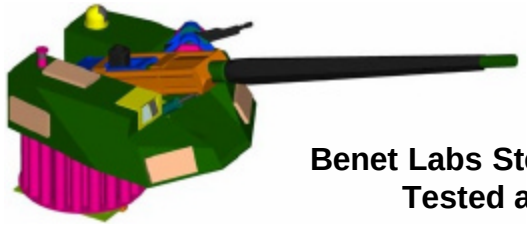
Decrease the weight, pull back the CG, increase the stiffness, increase the life, and increase the energy of large caliber gun tubes.

Technical Barriers:

- Steel Barrels
  - Lightweight Confinement Materials/Designs
  - Degradation of Composite Matrix
- Ceramic Barrels
  - Identify Suitable and Producible Ceramic Liners
  - Maintain Tri-axial Compressive State

Application:

FCS MRAAS



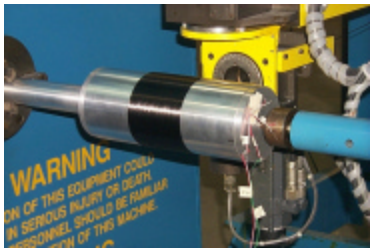
Benet Labs Steel/Composite Gun Tested at ARL Jan'02

Design Approaches:

Steel Barrels with PMC/MMC Composite Overwrap

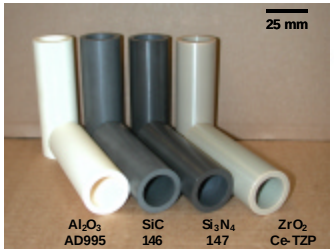
Analysis Techniques

Processing Techniques



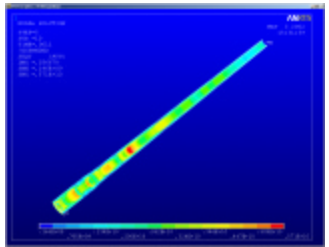
Ceramic Barrels with Confining Material Overwrap

Ceramic Material Characterization & Downselection

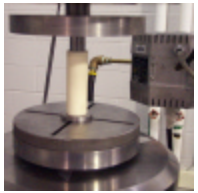


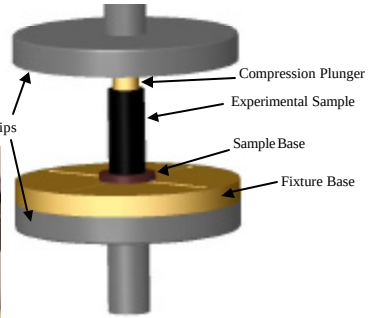
Probabilistic Analysis

Transient ThermoMechanical Modeling



Specialized Testing





Smart Cargo Munitions

Metal Matrix Composite and HYBOR shells offer >50% reduction in parasitic mass compared to steel, and >50% reduction in parasitic volume compared to graphite/epoxy

Objective:

1: Decrease the parasitic mass,
2: Increase the triaxial loading ability, and
3: Maximize the cargo volume
of ogive-heavy smart artillery munitions.

Technical Barriers:

- **Material Design Parameters**
  - PMC technology is mature
  - MMC technology is currently being matured for MRAAS smart cargo designs
- **Joint Design**
  - PMC shell joint designs successfully tested
  - MMC shell joints currently being investigated at ARL
- **Manufacturing**
  - PMC shell manufacturing technologies mature with broad industrial base
  - Only cost-effective MMC material is 3M's Nextel alumina fibers in aluminum matrix. Small but growing industrial base. High commercial growth. Several manufacturing issues to be addressed for scale-up.
- **Advanced Polymers**
  - Require novel polymer formulation/synthesis for specialized/unique requirements in munitions.
    - radomes: hi-temp, hi-performance, RF-transparent
    - electronics packaging: g-hardened, uniform CTE, tough

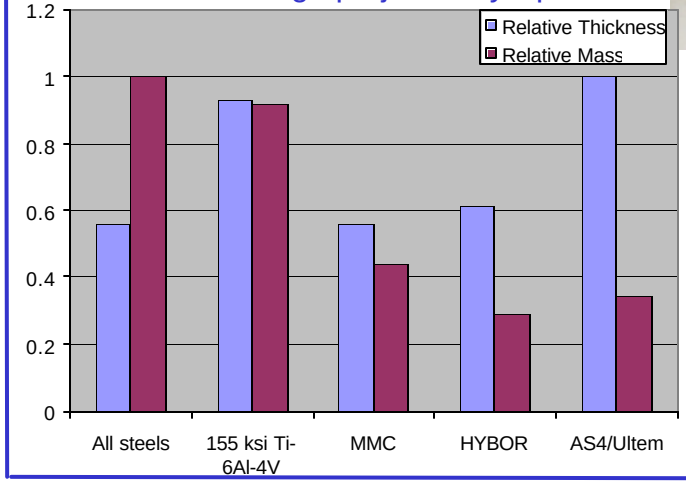
Design Approach:

Polymer-Matrix Composite Shells

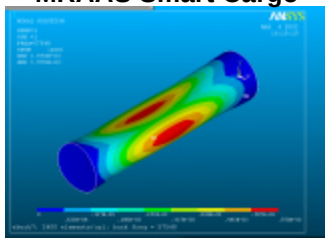
- shells 2/3 the weight of steel shells
- current technology

Metal-Matrix Composite Shells

- up to 1/3 weight reduction over steel for same volume
- developed analysis techniques
- performing building block characterization
- will fire MMC cargo projectile by Apr '03

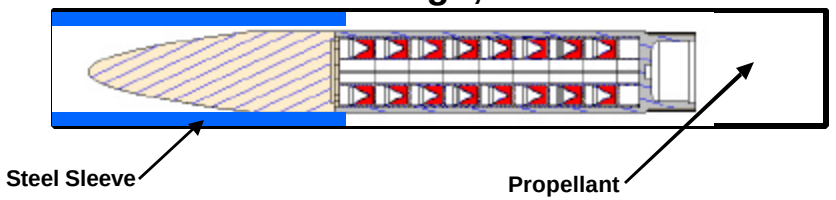


MMC Shell Buckling Analysis for CTA MRAAS Smart Cargo



Applications:

MRAAS Smart Cargo, XM892 Excalibur



SMART FINS

Objective:

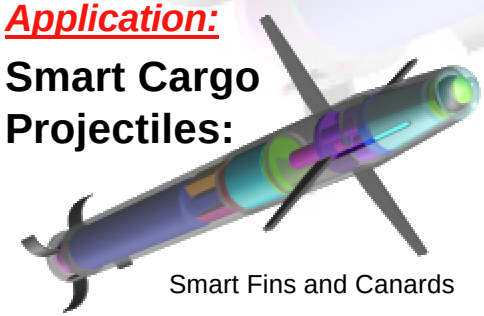
To use piezoelectric materials in fins to improve the accuracy of trajectories for projectiles during flight.

Technical Barriers:

- **Weight and power supply limitations.**
- **Launch and in-flight load requirements.**
- **Fin performance envelope to meet aerodynamic requirements.**
- **Deployment issues.**

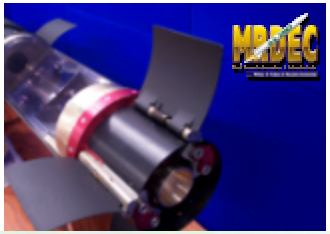
Application:

Smart Cargo Projectiles:



Smart Fins and Canards

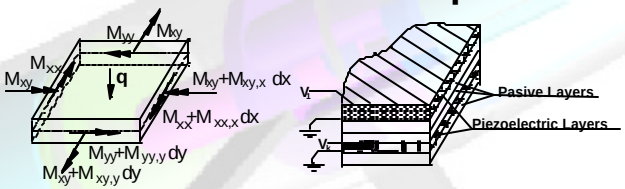
Missiles:



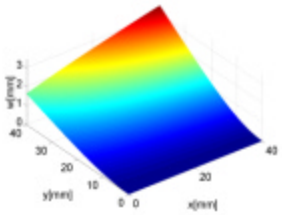
Smart Control Wing

Design Approach:

Theoretical Model Development



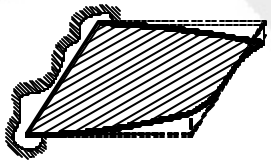
22nd Order ODE



Conceptual Design Study

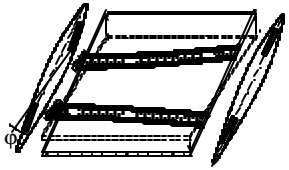
Twist Actuation

2.5 °

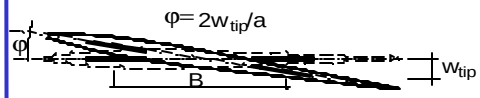


Double Beam

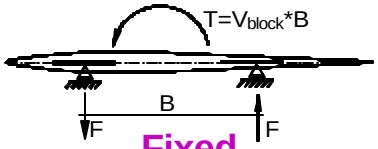
8.0 °



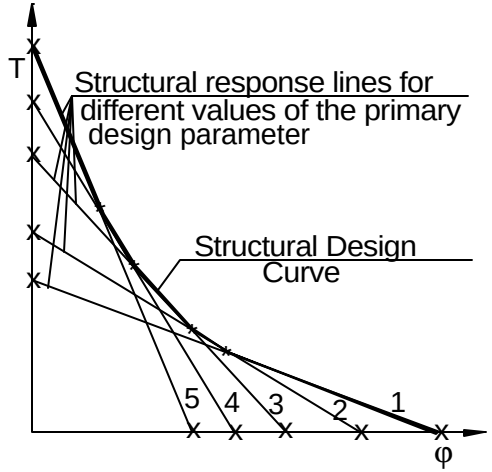
Design charts to define fin performance envelope.



Free Rotation



Fixed



Other Armament Components

Objective:

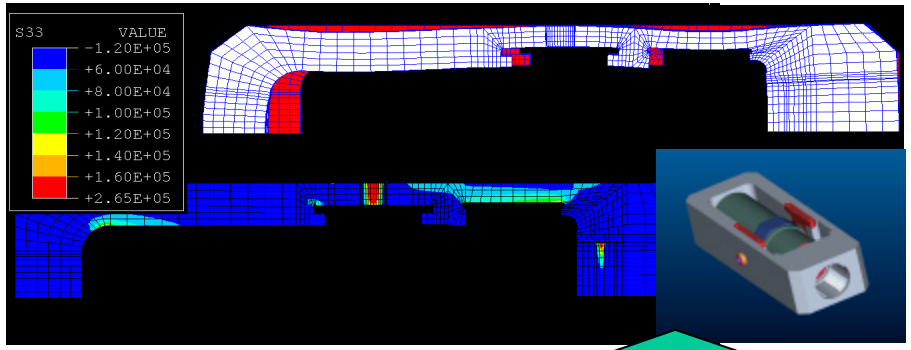
Decrease the weight and increase stiffness of critical armament components.

Technical Barriers:

- **Require simultaneous high stiffness and strength**
- **Integration of multiple materials is key to success**

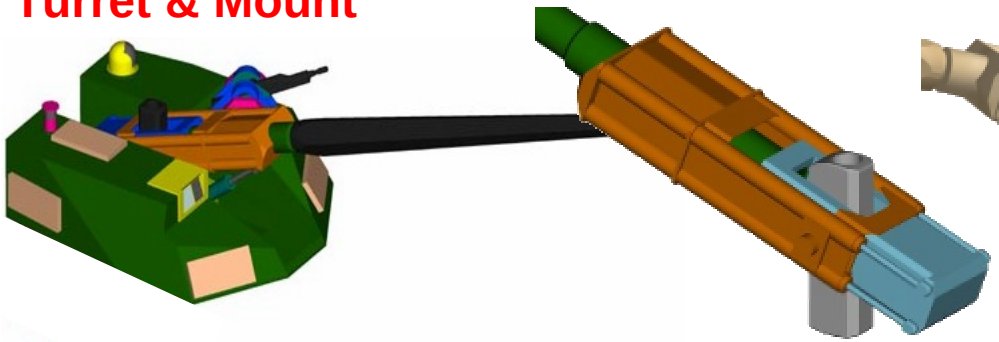
Design Approach:

Weight trade study on all components with detailed analysis and design of a composite/metal breech ring.



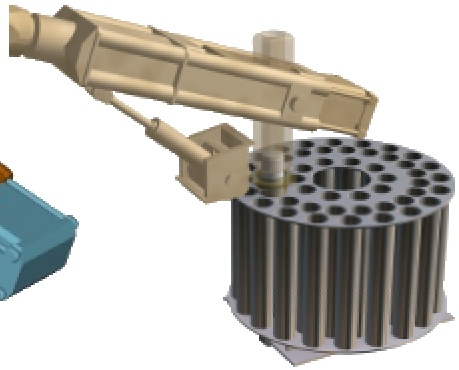
Applications: FCS MRAAS

Turret & Mount

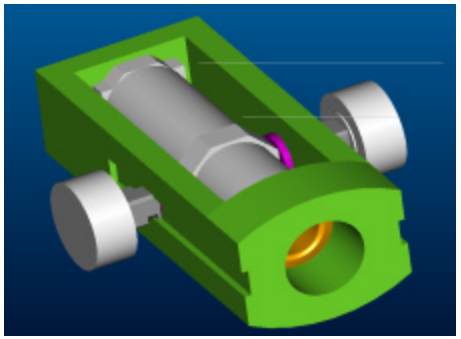


Swing Chamber

Ammunition Bustle



Breech Ring



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